CARMEUSE™
NATURAL CHEMICALS

TECHNICAL BULLETIN

Road Construction

Hydrated Lime and Quicklime

Lime for Soil Stabilization

and Soil Modification.

A Proven Solution.

Revision: 9/23/2002

The application of lime is a superior and commonly used method for soil modification and soil stabilization for subgrade beneath roadways, airfields, and parking lots. Lime can substantially increase subgrade stability, load bearing capacity, and long-term durability. More than one million tons of lime are used annually in the U.S. for soil modification and stabilization.

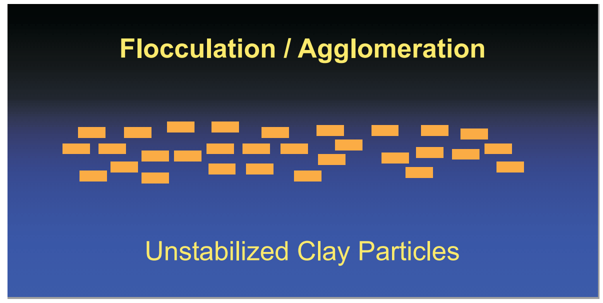
Lime, the Proven Solution!

CARMEUSE
NATURAL CHEMICALS

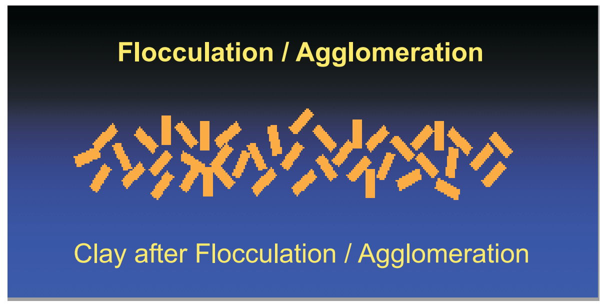
Carmeuse North America
11 Stanwix Street, 11th Floor
Pittsburgh, PA 15222

Phone: 412-995-5500
Fax: 412-995-5594
E-mail: info@carmeusena.com
Internet: www.carmeusena.com

Lime reacts chemically with clays to alter molecular interactions.

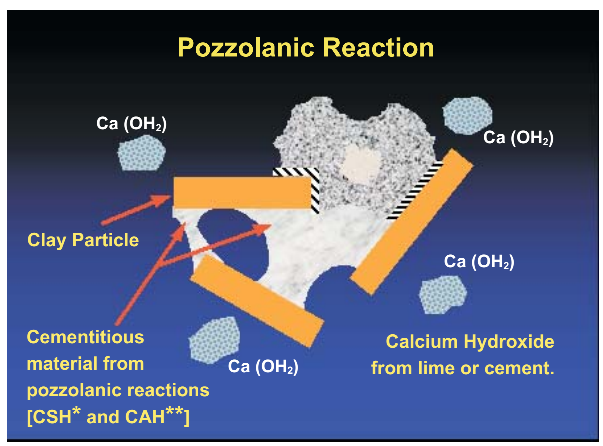


Untreated clays have a molecular structure similar to some polymers, and give plastic properties. The structure can trap water between its molecular layers, causing volume and density changes.



In treated clays, calcium atoms (from lime) replace sodium and hydrogen atoms producing a soil with very friable characteristics.

Pozzolanic reactions using lime-- Key to the treatment of clay soils.



On-going reaction with available silica and alumina in the soil forms complex cementitious materials-- the POZZOLANIC effect.

* Ca^{++} + OH^- + Soluble Clay Silica → Calcium Silicate Hydrate (CSH)

** Ca^{++} + OH^- + Soluble Clay Alumina → Calcium Aluminate Hydrate (CAH)

Soil Modification

Lime is an excellent choice for the short-term modification of soil properties. Lime can modify almost all fine-grained soils, but the most dramatic improvement occurs in clay soils of moderate to high plasticity. Modification occurs because calcium cations supplied by the hydrated lime replace the cations normally present on the surface of the clay mineral, promoted by the high pH environment of the lime-water system. The clay surface mineralogy is altered through particle flocculation/agglomeration, producing several benefits.

Benefits:

- Plasticity reduction
- Reduction in moisture-holding capacity (drying)
- Swell reduction
- Improved stability
- The ability to construct a solid working platform

Soil Stabilization

Soil stabilization occurs when lime is added to a reactive soil to generate long-term strength gain through a pozzolanic reaction. This reaction produces stable calcium silicate hydrates and calcium aluminate hydrates as the calcium from the lime reacts with the aluminates and silicates solubilized from the clay. The full-term pozzolanic reaction can continue for a very long period of time, even decades, as long as enough lime is present and the pH remains high (above 10). As a result, lime treatment can produce high and long-lasting strength gains. The key to pozzolanic reactivity and stabilization is a reactive soil, a good mix design protocol, and reliable construction practices.

Benefits:

- Very substantial increases in resilient modulus values (by a factor of 10 or more in many cases)
- Very substantial improvements in shear strength (by a factor of 20 or more in some cases)
- Continued strength gain with time, even after periods of environmental or load damage (autogenous healing)
- Long-term durability over decades of service even under severe environmental conditions

Lime Stabilization Lowers Pavement Cost

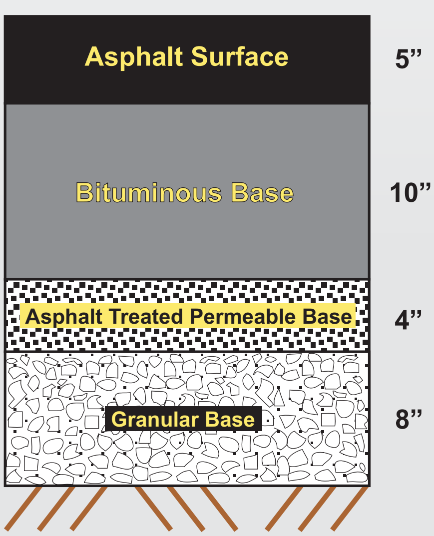
Stronger Subgrade -- Lower Pavement Cost

A recent study* on an interstate project in Pennsylvania shows that lime stabilization is cost effective. Alternate pavement sections were designed using the guidelines of the American Association of State Highway and Transportation Officials. The two alternates -- one utilizing lime stabilized subgrade and one with no stabilization -- were designed for the same traffic loads and service life.

Stabilizing the existing subgrade, rather than removing and replacing it with granular material, resulted in substantial cost savings. Additionally, because lime stabilization increases the subgrade strength and other desirable properties, the flexible pavement alternate designed on the lime stabilized subgrade could be thinner than the alternate without stabilization. The resulting savings -- over 20% -- saved the owner over $4 million.

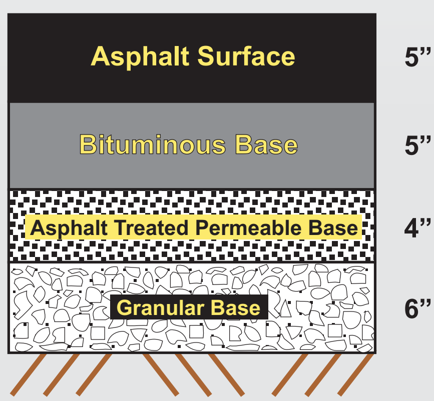
*(Qubain et al., *Incorporating Subgrade Lime Stabilization into Pavement Design*, Transportation Research Board Meeting, January 2000.)

Estimated Cost = $26.1 Million



Untreated Subgrade CBR = 8

Estimated Cost = $22.1 Million



Lime Stabilized Subgrade CBR = 15

Lime Stabilization Yields Over 20% Initial Cost Savings.

<table>
<tr><th>Soil Type</th><th>Well graded gravels and gravel-sand mixtures, little or no fines</th><th>Poorly graded gravels and gravel sand mixtures, little or no fines</th><th>Silty gravels, gravel-sand-silt mixtures</th><th>Clayey gravels, gravel-sand-clay mixtures</th><th>Well-graded sands and gravelly sands, little or no fines</th><th>Poorly graded sands and gravelly sands, little or no fines</th><th>Silty sands, sand-silt mixtures</th><th>Clayey sands, sand-clay mixtures</th><th>Inorganic silts, very fine sands, rock flour, silty or clayey fine sands</th><th>Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays</th><th>Organic silts and organic silty clays of low plasticity</th><th>Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts</th><th>Inorganic clays of high plasticity, fat clays</th><th>Organic clays of medium to high plasticity</th><th>Peat, muck, and other highly organic soils</th></tr>
<tr><td>Unified Group Symbol</td><td>GW</td><td>GP</td><td>GM</td><td>GC</td><td>SW</td><td>SP</td><td>SM</td><td>SC</td><td>ML</td><td>CL</td><td>OL</td><td>MH</td><td>CH</td><td>OH</td><td>PT</td></tr>
<tr><td>AASHTO Group Classification</td><td>A-1-a</td><td>A-1-a</td><td>A-1-b</td><td>A-1-b</td><td>A-1-b</td><td>A-1-b or A-3</td><td>A-2-4 or A-2-5</td><td>A-2-6 or A-2-7</td><td>A-4</td><td>A-6</td><td>A-4</td><td>A-5</td><td>A-7-6</td><td>A-7-5</td><td>A-8</td></tr>
<tr><td rowspan="2">Recommended Additives</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="7">LIME (Stabilization & Modification)</td><td></td></tr>
<tr><td colspan="9">LIME PLUS TYPE "F" Coal Fly Ash (Stabilization)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

LIME BASED MIX DESIGNS FOR DIFFERENT SOIL TYPES

Basic Construction Techniques

Lime stabilization is not difficult to carry out. After proper mix design and testing is performed, in-place mixing is usually used to add the appropriate amount of lime to soil, mixed to an appropriate depth. Typically, 3% to 8% lime based on dry weight of soil is used depending upon soil type and soil moisture content. Pulverization and mixing thoroughly combines the lime and soil. For heavy clays, preliminary mixing may be followed by 24 to 48 hours (or more) of moist curing, followed by final mixing. For maximum development of strength and durability, proper compaction is necessary. Proper curing is also important. If sulfates are present at levels greater than 0.3 percent, special procedures are required.

CARMEUSE™
NATURAL CHEMICALS

Carmeuse North America
11 Stanwix Street, 11th Floor
Pittsburgh, PA 15222

Phone: 412-995-5500
Fax: 412-995-5594
E-mail: info@carmeusena.com
Internet: www.carmeusena.com